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## I-ACT: Integrated study on effect of Activity on ComplicaTions in pregnancy – study protocol of a multiethnic prospective cohort study

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## MANUSCRIPT TITLE:

I-ACT: Integrated study on effect of Activity on ComplicaTions in

pregnancy – study protocol of a multi-ethnic prospective cohort study

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### Abstract

**Introduction:** Physical activity (PA) during first 20 weeks of pregnancy may lower risks of gestational diabetes mellitus (GDM) and gestational hypertension (GH), though evidence of association remains inconclusive. Current studies rely heavily on subjective assessment of PA levels. Wearable activity trackers provide a convenient and objective surrogate index for PA validated by evidence-based steps/day categorization along a physical inactivity/activity continuum. I-ACT primarily aims to examine objectively measured PA levels and patterns in first and second trimesters of pregnancy and the association with GDM and/or GH in Singapore, a multi-ethnic Asian population. Secondary aims include investigating the biosocio-demographic factors associated with sedentary behavior, and association of early pregnancy PA level with maternal weight at 6 weeks post-delivery. Results may facilitate identification of high-risk mothers-to-be and formulation of interventional strategies.

**Methods and analysis:** Prospective cohort study that will recruit 408 women at first antenatal visit at <12 weeks gestation. Baseline bio-socio-demographic factors and PA levels assessed by participant characteristics form and the International Physical Activity Questionnaire (IPAQ) respectively. An activity tracker (Fitbit) will be provided to be worn daily from date of recruitment to end of 20 weeks gestation. Tracker-recorded data will be synchronized with an application on participant's smartphone. Compliance will be reinforced with fortnightly reminders. After 20 weeks, a second IPAQ and a feedback form will be administered. GDM screened at 24-28 weeks gestation. GH diagnosed after 20 weeks gestation. Maternal weight assessed at 6 weeks post-delivery. Appropriate statistical tests will be used to compare continuous and categorical PA measurements between first and second trimesters. Logistic regression will be used to analyse associations.

**Ethics and dissemination:** Ethical approval obtained from the Centralised Institutional Review Board of SingHealth (reference 2017/2836). Dissemination of results will be via peer-reviewed research publications both online and in print, conference presentations, posters, and medical forums.

(299 words)

Keywords: Physical activity, gestational diabetes mellitus, pregnancy-induced hypertension, pregnancy

## Strengths and limitations of this study

- Prospective cohort study of a multi-ethnic Asian population
- Objective measurement of PA levels and patterns in early pregnancy
- Data collection designed to minimize recall bias
- Participant non-compliance despite reinforcement measures
- Participants' unfamiliarity with wearable activity tracker and mobile application despite education at recruitment

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### Introduction

Physical activity (PA) is defined as any bodily movement produced by skeletal muscles that results in energy expenditure<sup>1</sup>. Current recommendations encourage women with uncomplicated pregnancies to continue or initiate safe physical activities in pregnancy<sup>2</sup>. More specifically, the CDC recommends 30 min/day for five days each week of moderate-intensity aerobic activity, which can be met by walking<sup>3</sup>. Concerns about safety have been refuted by literature demonstrating that moderate exercise in low-risk pregnancy improves maternal well-being without associated risks of birth weight reduction or preterm birth<sup>4</sup>.

Physical inactivity or sedentary behavior in early pregnancy (<20 weeks gestation) is a potential modifiable risk factor for two common obstetric complications, gestational diabetes mellitus (GDM) and gestational hypertension (GH). GDM is defined as carbohydrate intolerance that develops during pregnancy<sup>5</sup>. It complicates 1.8-25.1% of pregnancies worldwide depending on country and definition, with South-East Asia having the second highest prevalence at 8.1-18.3<sup>6</sup>. Approximately 8-20% of pregnancies are affected in Singapore<sup>7</sup>. Overall prevalence of GH, otherwise known as pregnancy-induced hypertension, is estimated at 10-12%<sup>8,9</sup>, though the local incidence has not been established. Perinatal sequelae of GDM and GH include macrosomia, neonatal hypoglycemia, preterm birth, intrauterine growth restriction (IUGR), and low APGAR scores. Both metabolic disorders are also proven risk factors of future type 2 diabetes<sup>10</sup>.

Current literature investigating the association between PA in early pregnancy and the development of GDM has shown a significant risk reduction of up to 24%<sup>11-14</sup>, though a few other studies have found a null association<sup>15,16</sup>. The association with GH is even less clear from the limited literature available<sup>17-20</sup>. All these studies utilised questionnaires as a measurement of PA. Studies that incorporate an objective means of measurement have been scarce<sup>21,22</sup>, which may partially explain the inconclusive evidence of association thus far. A Norway-based study investigating objectively recorded PA in early pregnancy and GDM reported that the adjusted odds ratio for GDM decreased 19% with every 3159 step-increase per day<sup>21</sup>. Based on these existing studies, physical inactivity in early pregnancy is a modifiable risk factor worth targeting

This is especially so in the Asian population. PA during first half of pregnancy has been shown to be low in an Asian urban setting<sup>23</sup>, and similarly lower when compared to non-Asian counterparts<sup>22,24</sup>. In Singapore, no published study on objectively measured PA levels in pregnancy could be found, and studies on association of subjectively-measured early pregnancy PA levels with both obstetric complications are rare. Padmapriya *et al.* investigated the change in PA levels from a pre-pregnancy to pregnancy state using a structured self-constructed questionnaire administered at 26-28 weeks gestation scored based on the International Physical Activity Questionnaire (IPAQ) short form<sup>25</sup>. The same study group further reported that a higher PA during the first 6 months of pregnancy was associated with lower prevalence of GDM, especially among overweight/obese women<sup>26</sup>. However, the utilisation of a questionnaire at 26-28 weeks gestation that relied on recall of PA levels during first 6 months of pregnancy and the year before subjected the results to a high level of recall bias. Therefore, the paucity of local research on objectively-measured PA levels in early pregnancy and association with obstetric metabolic outcomes warrants additional prospective studies.

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As evident from existing studies, current assessment of pregnancy PA levels relies heavily on subjective, self-reporting questionnaires deemed to be the most feasible method with the absence of a gold standard and clear guidelines<sup>27</sup>. The inclusion of more objective measurements is being advocated<sup>28</sup>. Consumer wearable activity trackers operate through a 3-axis accelerometer, providing an alternative convenient and objective means of assessing PA levels during pregnancy. The accuracy, reliability and efficacy of wearable activity trackers in various health programs have been validated $^{29-32}$ . Steps per day categorization along a physical inactivity/activity continuum based on CDC recommendation has also been elucidated, with 5000 (sedentary) and 10,000 (active) being the primary anchor points<sup>33</sup>. The correlation between steps per day and activity counts per day, from which activity intensity and duration were derived, was proven to be positive and strong, thus validating its use as an index for PA<sup>34</sup>. Step count estimated by Fitbit activity trackers in particular has also been validated in a separate study<sup>35</sup>. Through the use of both Fitbit activity trackers and the IPAQ, this prospective multi-ethnic cohort study primarily aims to investigate the PA levels and patterns in early pregnancy (1st trimester and 2nd trimester up to 20 weeks gestation), as well as the effect of PA in early pregnancy on development of GDM and/or GH. Secondary aims include assessing the bio-socio-demographic factors associated with sedentary behavior, and examining the association between early pregnancy PA level and maternal weight at 6 weeks post-delivery. 

## Methods and analysis

## Study design

In this prospective cohort study, pregnant women will be recruited at outpatient clinics in KK Women's and Children's Hospital, a major public hospital in Singapore that sees a high volume of obstetrics & gynaecology consultations.

## Recruitment and eligibility criteria

All obstetricians running outpatient general obstetrics & gynaecology clinics will refer suitable candidates for recruitment. All recruitment will be done via face-to-face contact by the research team.

Inclusion criteria are singleton pregnancy, first antenatal visit less than 12 weeks gestation, and ages between 21 and 50 years old inclusive. Exclusion criteria are severe medical and/or psychological co-morbidity (including New York Heart Association (NYHA) class IV heart failure, end-stage renal disease, assistive device-dependent for mobility, cognitive impairment, and loss of rational thinking), and skin conditions (including contact dermatitis, pemphigus vulgaris and bullous pemphigoid) precluding the wearing of activity trackers.

## Power analysis

Given that prevalence of GH has not been investigated in Singapore, GDM prevalence is used instead. Assuming that GDM proportion is  $17.6\%^{36}$  and that PA can reduce risk of GDM by 30%, a sample of 367 mothers will be required at 80% power and 5% level of significance. Assuming a dropout rate of 10%, a sample of 408 mothers will be recruited into the study.

## Participant timeline

Recruitment is at first antenatal visit less than 12 weeks gestation, during which Fitbit education, International Physical Activity Questionnaire (IPAQ) and participant characteristics form are done (Fig. 1). PA level monitoring occurs henceforth until end of 20 weeks gestation inclusive. The standard 4-weekly antenatal visits will continue during this period. After 20 weeks gestation, a second IPAQ and a feedback form are administered either at regular antenatal visits before 24 weeks gestation, or over the phone/email. Routine GDM screening takes place between 24 and 28 weeks gestation. The final follow-up occurs at the 6th week after delivery to obtain participants' weight.

## **Ensuring compliance**

Approaches to enhance compliance include reinforcing the importance of commitment to wearing the activity trackers daily at the time of recruitment, and making fortnightly follow-

up calls up until 20 weeks gestation. Compliance will also be recorded as part of Fitbit use assessment in the participant feedback form at the end of 20 weeks gestation.

#### **Outcome measures**

Primary outcomes include the following:

- GDM diagnosed if the following threshold value at any time point is exceeded after a 75 g oral glucose tolerance test (OGTT) between 24 and 28 weeks gestation based on the International Association of Diabetes and Pregnancy Study Groups (IADPSG) criteria: fasting venous plasma glucose of ≥5.1 mmol/L, 1-hour venous plasma glucose of ≥10.0 mmol/L, and 2-hour venous plasma glucose ≥8.5 mmol/L<sup>37</sup>.
- GH diagnosed as new onset hypertension (systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg) measured on two occasions at least four hours apart after 20 weeks gestation in the absence of proteinuria or new signs of endorgan dysfunction<sup>38</sup>.

Secondary outcomes include the following:

- Weight at 6 weeks post-delivery
- Weight gain in pregnancy
- · Intrauterine growth restriction (IUGR)
- Preterm birth (GA  $\leq$ 37 weeks)
- Macrosomia (BW >4.5kg)
- Neonatal hypoglycemia (glucose <2.5 mmol/L)
- · Pre-eclampsia
- · APGAR scores

## **Data collection**

## Research participant characteristics form

Sociodemographic data to be assessed include marital status, educational level, household income, type of housing, working status during pregnancy, smoking status, and alcohol consumption. Medical history including pre-pregnancy height and weight, parity, history of infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of DM, and reasons behind potential PA restriction during early pregnancy will also be collected.

## Fitbit activity tracker and mobile application

At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education on device and application will be carried out. The tracker is worn daily from recruitment to end of 20 weeks gestation inclusive, except during bathing or water activities. Participants are advised to synchronize the tracker data at least once a week. For data to be valid, wear-time must be at least 4 days per week (including one weekend day) and at least 10 hours per day.

Steps per day will be recorded by the tracker. Data will be reported as continuous and categorical variables. Continuous variables include mean weekday and weekend steps per day and mean steps per day in first and second trimesters. Categorical variables include classification into a CDC recommendation-based steps per day physical inactivity/activity continuum defined as follows: (1) <5000 (sedentary); (2) 5000-7499 (low active); 3) 7500-9999 (somewhat active); 4) 10,000-12,499 (active); and 5)  $\geq$ 12,500 (highly active)<sup>33</sup>.

#### International Physical Activity Questionnaire (IPAQ)

The IPAQ long version will be self-administered during the first visit at less than 12 weeks gestation in the first trimester and again between 20-24 weeks gestation in the second trimester. It is a set of 4 questionnaires assessing 5 activity domains (occupation, transportation, household, leisure, and sedentary) independently in the past 7 days, and may be administered via self or telephone<sup>39</sup>. Well-established and validated in adults aged 15-69 years, it is available in both English and Chinese<sup>40,41</sup>. It has been used in studies involving pregnant women<sup>28,42</sup>.

Data will be reported as continuous and categorical variables. Continuous variables include median MET-minutes per week (MET-min/wk) and interquartile ranges computed for each domain, subdomain (walking, moderate-intensity PA and vigorous-intensity PA) and overall total PA. MET or metabolic equivalent is a unit that measures energy expenditure in multiples of the resting metabolic rate<sup>43</sup>. Categorical variables include classification into low, moderate, high levels of PA according to the IPAQ scoring protocol.

## Medical record data

Additional data to be collected include ethnicity, weight changes during pregnancy, weight at 6 weeks post-delivery, obstetric outcomes of GDM, GH, preeclampsia and IUGR, and neonatal outcomes comprising APGAR scores, preterm birth, macrosomia, and neonatal hypoglycemia.

## Participant feedback form

After the end of 20 weeks gestation, experience with the activity tracker and mobile application in terms of usability and troubleshooting will be evaluated. Compliance level will be quantified by number of days per week.

## Statistics

Descriptive statistics of PA levels in the 1st and early 2nd trimester will be presented. Mean steps per day and median MET-minutes per week between semesters will be compared using paired Student's t-test and Wilcoxon signed-rank test respectively. McNemar's test will be used to compare sedentary behavior between semesters. Similar tests will be used to assess for a difference in PA levels between weekdays and weekends.

Logistic regression will be used to evaluate bio-socio-demographic factors associated with sedentary behavior, and the effect of early pregnancy PA on GDM and/or GH.

Statistical analyses will be performed using IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, N.Y., USA). *P* values of <0.05 will be considered statistically significant.

#### Safety parameters

Adverse effects and device monitoring will be carried out at the subsequent 4-weekly routine prenatal visits. Any adverse skin reaction to the wristband will be recorded. Participation will be stopped at any time the Principal Investigator decides that continuing on could be harmful to the participant.

## Data management

All data will be coded for confidentiality. Hardcopy data will be stored at the research site under lock and key. Electronic data can only be accessed and retrieved from the secured website by the participant and research team. All data obtained will be entered into and stored on the institution Research Electronic Data Capture (REDCap) system, a centralised secured data management server with password access. Data integrity monitoring will be carried out monthly by the principal investigator and co-investigators if deemed necessary.

Ethics and dissemination

Ethical approval was obtained from the Centralised Institutional Review Board of SingHealth (reference 2017/2836). Informed written consent will be sought from all participants.

Results from this study will be submitted to the funding organization and peer-reviewed journals for consideration of publication both online and in print. Results will also be presented at relevant meetings, conferences and medical forums in either oral or poster formats.

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Conclusion

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The I-ACT study aims to be the first comprehensive study objectively evaluating the PA levels and patterns in early pregnancy, and their association with GDM and/or GH in the multi-ethnic population of Singapore. In addition to addressing these important scientific knowledge gaps, from a clinical perspective, the study itself may increase awareness of PA during early pregnancy while demonstrating the potential of wearable activity trackers as an objective measure of PA in health research. More importantly, we hope the results of the study facilitate the identification of high-risk mothers-to-be for targeted intervention, and help formulate strategies for interventional efforts.

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## Author statement

MC was involved in all aspects of the study from conception, design, recruitment and manuscript writing. KHT and SBA provided critical review of the design and writing. As

Principle Investigator, SBA takes overall responsibility for the work. All authors agree to be accountable for their work.

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Conflict of interests

The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

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<sup>†</sup>Participants will continue to attend routine antenatal visits throughout the study period during which blood pressure monitoring will be done

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#### Abstract

Introduction: Physical activity (PA) during first 20 weeks of pregnancy may lower risks of gestational diabetes mellitus (GDM) and gestational hypertension (GH), though evidence of association remains inconclusive. Current studies rely heavily on subjective assessment of PA levels. Wearable activity trackers provide a convenient and objective surrogate index for PA validated by evidence-based steps/day categorization along a physical inactivity/activity continuum. I-ACT primarily aims to examine objectively measured PA levels and patterns in first and second trimesters of pregnancy and the association with GDM and/or GH in Singapore, a multi-ethnic Asian population. Secondary aims include investigating the bio-socio-demographic factors associated with sedentary behavior, and association of early pregnancy PA level with maternal weight at 6 weeks post-delivery. Results may facilitate identification of high-risk mothers-to-be and formulation of interventional strategies. Methods and analysis: Prospective cohort study that will recruit 408 women at first antenatal visit at <12 weeks gestation. Baseline bio-socio-demographic factors and PA levels assessed by participant characteristics form and the International Physical Activity Questionnaire (IPAQ) respectively. An activity tracker (Fitbit) will be provided to be worn daily from date of recruitment to end of 20 weeks gestation. Tracker-recorded data will be synchronized with an application on participant's smartphone. Compliance will be reinforced with fortnightly reminders. After 20 weeks, a second IPAQ and a feedback form will be administered. GDM screened at 24-28 weeks gestation. GH diagnosed after 20 weeks gestation. Maternal weight assessed at 6 weeks post-delivery. Appropriate statistical tests will be used to compare continuous and categorical PA measurements between first and second trimesters. Logistic regression will be used to analyse associations. Ethics and dissemination: Ethical approval obtained from the Centralised Institutional Review Board of SingHealth (reference 2017/2836). Dissemination of results will be via peer-reviewed research publications both online and in print, conference presentations, posters, and medical forums. (299 words) Keywords: Physical activity, gestational diabetes mellitus, pregnancy-induced hypertension, pregnancy 

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#### Introduction

Physical activity (PA) is defined as any bodily movement produced by skeletal muscles that 

- results in energy expenditure<sup>1</sup>. Current recommendations encourage women with
- uncomplicated pregnancies to continue or initiate safe physical activities in pregnancy<sup>2</sup>. More
- specifically, the CDC recommends 30 min/day for five days each week of moderate-intensity
- aerobic activity, which can be met by walking<sup>3</sup>. Concerns about safety have been refuted by
- literature demonstrating that moderate exercise in low-risk pregnancy improves maternal
- well-being without associated risks of birth weight reduction or preterm birth<sup>4</sup>.
- Physical inactivity or sedentary behavior in early pregnancy (<20 weeks gestation) is a
- potential modifiable risk factor for two common obstetric complications, gestational diabetes
- mellitus (GDM) and gestational hypertension (GH). GDM is defined as carbohydrate
- intolerance that develops during pregnancy<sup>5</sup>. It complicates 1.8-25.1% of pregnancies worldwide depending on country and definition, with South-East Asia having the second
- highest prevalence at 8.1-18.3<sup>6</sup>. Approximately 8-20% of pregnancies are affected in
- Singapore<sup>7</sup>. Overall prevalence of GH, otherwise known as pregnancy-induced hypertension,
- is estimated at 10-12%<sup>8,9</sup>, though the local incidence has not been established. Perinatal
- sequelae of GDM and GH include macrosomia, neonatal hypoglycemia, preterm birth,
- intrauterine growth restriction (IUGR), and low APGAR scores. Both metabolic disorders are
- also proven risk factors of future type 2 diabetes<sup>10</sup>.
- Current literature investigating the association between PA in early pregnancy and the development of GDM has shown a significant risk reduction of up to 24%<sup>11-14</sup>, though a few other studies have found a null association or insufficient evidence<sup>15-17</sup>. The association with GH is even less clear from the limited literature available<sup>18-21</sup>. All these studies utilised questionnaires as a measurement of PA. Studies that incorporate an objective means of measurement have been scarce<sup>22,23</sup>, which may partially explain the inconclusive evidence of association thus far. A Norway-based study investigating objectively recorded PA in early pregnancy and GDM reported that the adjusted odds ratio for GDM decreased 19% with every 3159 step-increase per day<sup>22</sup>. Based on these existing studies, physical inactivity in early pregnancy is a modifiable risk factor worth targeting
- This is especially so in the Asian population. PA during first half of pregnancy has been shown to be low in an Asian urban setting<sup>24</sup>, and similarly lower when compared to non-Asian counterparts<sup>23,25</sup>. In Singapore, no published study on objectively measured PA levels in pregnancy could be found, and studies on association of subjectively-measured early pregnancy PA levels with both obstetric complications are rare. Padmapriva et al. investigated the change in PA levels from a pre-pregnancy to pregnancy state using a structured self-constructed questionnaire administered at 26-28 weeks gestation scored based on the International Physical Activity Questionnaire (IPAQ) short form<sup>26</sup>. The same study group further reported that a higher PA during the first 6 months of pregnancy was associated with lower prevalence of GDM, especially among overweight/obese women<sup>27</sup>. However, the utilisation of a questionnaire at 26-28 weeks gestation that relied on recall of PA levels during first 6 months of pregnancy and the year before subjected the results to a high level of recall bias. Therefore, the paucity of local research on objectively-measured PA levels in early pregnancy and association with obstetric metabolic outcomes warrants additional prospective studies.

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155	As evident from existing studies, current assessment of pregnancy PA levels relies heavily on
156	subjective, self-reporting questionnaires deemed to be the most feasible method with the
157	absence of a gold standard and clear guidelines <sup>28</sup> . The inclusion of more objective
158	measurements is being advocated <sup>29</sup> . Consumer wearable activity trackers operate through a 3-
159	axis accelerometer, providing an alternative convenient and objective means of assessing PA
160	levels during pregnancy. The accuracy, reliability and efficacy of wearable activity trackers
161	in various health programs have been validated <sup>30-33</sup> , although a systematic review has found
162	the research-grade accelerometer or pedometer to be superior in terms of accuracy <sup>34</sup> . Steps
163	per day categorization along a physical inactivity/activity continuum based on CDC
164	recommendation has also been elucidated, with 5000 (sedentary) and 10,000 (active) being
165	the primary anchor points <sup>35</sup> . The correlation between steps per day and activity counts per
166	day, from which activity intensity and duration were derived, was proven to be positive and
167	strong, thus validating its use as an index for PA <sup>36</sup> . Step count estimated by Fitbit activity
168	trackers among healthy adults has also been validated in a separate study <sup>37</sup> . Furthermore,
169	various measured parameters such as step count and moderate-to-vigorous PA (MVPA) of
170	different Fitbit activity trackers models have also been validated in the particular population
171	of pregnant women in free living conditions <sup>38</sup> .
177	Through the use of both Fithit activity trackers and the $IPAO$ , this prospective multi-ethnic
173	cohort study primarily aims to investigate the PA levels and patterns in early pregnancy (1st
174	trimester and 2nd trimester up to 20 weeks gestation) as well as the effect of PA in early
175	pregnancy on development of GDM and/or GH. Secondary aims include assessing the bio-
176	socio-demographic factors associated with sedentary behavior, and examining the association
177	between early pregnancy PA level and maternal weight at 6 weeks post-delivery.
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#### Methods and analysis

#### **Study design**

In this prospective cohort study, pregnant women will be recruited at outpatient clinics in KK Women's and Children's Hospital, a major public hospital in Singapore that sees a high volume of obstetrics & gynaecology consultations. Recruitment started in June 2018 and is expected to end in 2019. This study will follow the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline for cohort studies. 

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#### **Recruitment and eligibility criteria**

All obstetricians running outpatient general obstetrics & gynaecology clinics will refer suitable candidates for recruitment. All recruitment will be done via face-to-face contact by the research team. 

Inclusion criteria are singleton pregnancy, first antenatal visit less than 12 weeks gestation, and ages between 21 and 50 years old inclusive. Exclusion criteria are severe medical and/or psychological co-morbidity (including New York Heart Association (NYHA) class IV heart failure, end-stage renal disease, assistive device-dependent for mobility, cognitive 

impairment, and loss of rational thinking), and skin conditions (including contact dermatitis, pemphigus vulgaris and bullous pemphigoid) precluding the wearing of activity trackers. 

#### **Power analysis**

Given that prevalence of GH has not been investigated in Singapore, GDM prevalence is used instead. Assuming that GDM proportion is 17.6%<sup>39</sup> and that PA can reduce risk of GDM by 30%, a sample of 367 mothers will be required at 80% power and 5% level of significance. Assuming a dropout rate of 10%, a sample of 408 mothers will be recruited into the study. 

#### **Participant timeline**

Recruitment is at first antenatal visit less than 12 weeks gestation, during which Fitbit education, International Physical Activity Questionnaire (IPAQ) and participant characteristics form are done (Fig. 1). PA level monitoring occurs henceforth until end of 20 weeks gestation inclusive. The standard 4-weekly antenatal visits will continue during this period. After 20 weeks gestation, a second IPAQ and a feedback form are administered either at regular antenatal visits before 24 weeks gestation, or over the phone/email. Routine GDM screening takes place between 24 and 28 weeks gestation. The final follow-up occurs at the 6th week after delivery to obtain participants' weight. 

#### **Ensuring compliance**

Approaches to enhance compliance include reinforcing the importance of commitment to         wearing the activity trackers daily at the time of recruitment, and making fortnightly follow-         up calls up unit 20 weeks gestation. Compliance will also be recorded as part of Fitbit use         assessment in the participant feedback form at the end of 20 weeks gestation.         234         235       Outcome measures         236       Primary outcomes include the following:         237       GDM – diagnosed if the following threshold value at any time point is exceeded after         238       a 75 g oral glucose tolerance test (OGTT) between 24 and 28 weeks gestation based         239       on the International Association of Diabetes and Pregnancy Study Groups (IADPSG)         240       criteria: fasting venous plasma glucose of ≥5.1 mmol/L. <sup>40</sup> 241       glucose of ≥10.0 mmol/L, and 2-hour venous plasma glucose ≥8.5 mmol/L <sup>40</sup> .         242       GH – diagnosed as new onset hypertension (systolic blood pressure ≥100 mmHg)         243       and/or diastolic blood pressure ≥00 mmHg) measured on two occasions at least four         244       bours apart after 20 weeks gestation in the absence of proteinuria or new signs of end-         255       Secondary outcomes include the following:         256       Preterm birth (GA <37 weeks)         257       Neonatal hypoglycemia (glucose <2.5 mmol/L) <td< th=""><th>1</th><th></th><th></th></td<>	1		
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<ul> <li>241 GHC- diagnosed as new onset hypertension (systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg) measured on two occasions at least four hours apart after 20 weeks gestation in the absence of proteinuria or new signs of end- organ dysfunction<sup>41</sup>.</li> <li>246 Secondary outcomes include the following:</li> <li>247 Weight at 6 weeks post-delivery</li> <li>248 Weight gain in pregnancy</li> <li>249 Intrauterine growth restriction (IUGR)</li> <li>250 Preterm birth (GA &lt;37 weeks)</li> <li>251 Macrosomia (BW &gt;4.5kg)</li> <li>252 Neonatal hypoglycemia (glucose &lt;2.5 mmol/L)</li> <li>253 Pre-eclampsia</li> <li>254 APGAR scores</li> <li>255</li> <li>255</li> <li>256</li> <li>257 <i>Research participant characteristics form</i></li> <li>258 Sociodemographic data to be assessed include marital status, educational level, household income, type of housing, working status during pregnancy, smoking status, and alcohol consumption. Medical history including pre-pregnancy height and weight, parity, history of infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of DM, and reasons behind potential PA restriction during early pregnancy will also be collected.</li> <li>264</li> <li>264</li> <li>265 <i>Fithit activity tracker and mobile application</i></li> <li>266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be connected via Bluctooth to a Fitbit application downloaded onto her smartphone. Education on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	19	240	$f_{\rm min}$ shows plasma glucose of $\leq 10.0$ mmol/L and 2-hour venous plasma glucose >8.5 mmol/L $^{40}$
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244       hours apart after 20 weeks gestation in the absence of proteinuria or new signs of end- organ dysfunction <sup>41</sup> .         245       organ dysfunction <sup>41</sup> .         246       Secondary outcomes include the following:         247       Weight at 6 weeks post-delivery         248       Weight gain in pregnancy         249       Intrauterine growth restriction (IUGR)         250       Preterm birth (GA <37 weeks)	22	243	and/or diastolic blood pressure $\geq 90 \text{ mmHg}$ ) measured on two occasions at least four
245       organ dysfunction <sup>41</sup> .         246       Secondary outcomes include the following:         247       . Weight at 6 weeks post-delivery         248       . Weight gain in pregnancy         219       . Intrauterine growth restriction (IUGR)         220       . Preterm birth (GA <37 weeks)	23	244	hours apart after 20 weeks gestation in the absence of proteinuria or new signs of end-
<ul> <li>246 Secondary outcomes include the following:</li> <li>247 · Weight at 6 weeks post-delivery</li> <li>248 · Weight gain in pregnancy</li> <li>249 · Intrauterine growth restriction (IUGR)</li> <li>250 · Preterm birth (GA &lt;37 weeks)</li> <li>251 · Macrosomia (BW &gt;4.5kg)</li> <li>252 · Neonatal hypoglycemia (glucose &lt;2.5 mmol/L)</li> <li>253 · Pre-eclampsia</li> <li>254 · APGAR scores</li> <li>255</li> <li>257 <i>Research participant characteristics form</i></li> <li>258 Sociodemographic data to be assessed include marital status, educational level, household income, type of housing, working status during pregnancy, smoking status, and alcohol consumption. Medical history including pre-pregnancy height and weight, parity, history of infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of DM, and reasons behind potential PA restriction during early pregnancy will also be collected.</li> <li>264</li> <li>264</li> <li>265 <i>Fitbit activity tracker and mobile application</i></li> <li>266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	25	245	organ dysfunction <sup>41</sup> .
<ul> <li>247 Weight at 6 weeks post-delivery</li> <li>248 Weight gain in pregnancy</li> <li>249 Intrauterine growth restriction (IUGR)</li> <li>250 Preterm birth (GA &lt;37 weeks)</li> <li>251 Macrosomia (BW &gt;4.5kg)</li> <li>252 Neonatal hypoglycemia (glucose &lt;2.5 mmol/L)</li> <li>253 Pre-eclampsia</li> <li>254 APGAR scores</li> <li>255</li> <li>255</li> <li>256</li> <li>257 Research participant characteristics form</li> <li>258 Sociodemographic data to be assessed include marital status, educational level, household income, type of housing, working status during pregnancy, smoking status, and alcohol</li> <li>259 consumption. Medical history including pre-pregnancy height and weight, parity, history of infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of DM, and reasons behind potential PA restriction during early pregnancy will also be collected.</li> <li>264</li> <li>264</li> <li>264</li> <li>265 Fibbit activity tracker and mobile application</li> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>260 on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	26 27	246	Secondary outcomes include the following:
<ul> <li>248 Weight gain in pregnancy</li> <li>249 Intrauterine growth restriction (IUGR)</li> <li>250 Preterm birth (GA &lt;37 weeks)</li> <li>251 Macrosomia (BW &gt;4.5kg)</li> <li>252 Neonatal hypoglycemia (glucose &lt;2.5 mmol/L)</li> <li>253 Pre-eclampsia</li> <li>254 APGAR scores</li> <li>255</li> <li>255</li> <li>256 Data collection</li> <li>257 <i>Research participant characteristics form</i></li> <li>258 Sociodemographic data to be assessed include marital status, educational level, household income, type of housing, working status during pregnancy, smoking status, and alcohol consumption. Medical history including pre-pregnancy height and weight, parity, history of DM, and reasons behind potential PA restriction during early pregnancy will also be collected.</li> <li>264</li> <li>265 <i>Fitbit activity tracker and mobile application</i></li> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	28	247	· Weight at 6 weeks post-delivery
<ul> <li>Intrauterine growth restriction (IUGR)</li> <li>Preterm birth (GA &lt;37 weeks)</li> <li>Macrosomia (BW &gt;4.5kg)</li> <li>Neonatal hypoglycemia (glucose &lt;2.5 mmol/L)</li> <li>Pre-eclampsia</li> <li>Pre-eclampsia</li> <li>APGAR scores</li> <li>APGAR scores</li> <li>Sociodemographic data to be assessed include marital status, educational level, household income, type of housing, working status during pregnancy, smoking status, and alcohol consumption. Medical history including pre-pregnancy height and weight, parity, history of infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of DM, and reasons behind potential PA restriction during early pregnancy will also be collected.</li> <li><i>Fitbit activity tracker and mobile application</i></li> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	29	248	· Weight gain in pregnancy
<ul> <li>Preterm birth (GA &lt;37 weeks)</li> <li>Macrosomia (BW &gt;4.5kg)</li> <li>Macrosomia (BW &gt;4.5kg)</li> <li>Neonatal hypoglycemia (glucose &lt;2.5 mmol/L)</li> <li>Pre-eclampsia</li> <li>APGAR scores</li> <li>APGAR scores</li> <li>Sociodemographic data to be assessed include marital status, educational level, household income, type of housing, working status during pregnancy, smoking status, and alcohol consumption. Medical history including pre-pregnancy height and weight, parity, history of infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of DM, and reasons behind potential PA restriction during early pregnancy will also be collected.</li> <li><i>Fitbit activity tracker and mobile application</i></li> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	30	249	· Intrauterine growth restriction (IUGR)
<ul> <li>Arcentin of H (GK S) weeks)</li> <li>Macrosomia (BW &gt;4.5kg)</li> <li>Neonatal hypoglycemia (glucose &lt;2.5 mmol/L)</li> <li>Pre-eclampsia</li> <li>APGAR scores</li> <li>APGAR scores</li> <li>Sociodemographic data to be assessed include marital status, educational level, household income, type of housing, working status during pregnancy, smoking status, and alcohol consumption. Medical history including pre-pregnancy height and weight, parity, history of infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of DM, and reasons behind potential PA restriction during early pregnancy will also be collected.</li> <li><i>Fitbit activity tracker and mobile application</i></li> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	32	250	· Preterm hirth $(G\Lambda < 37 \text{ weeks})$
<ul> <li>Macrosofina (fbw &gt;4.3kg)</li> <li>Neonatal hypoglycemia (glucose &lt;2.5 mmol/L)</li> <li>Pre-eclampsia</li> <li>APGAR scores</li> <li>APGAR scores</li> <li>Sociodemographic data to be assessed include marital status, educational level, household income, type of housing, working status during pregnancy, smoking status, and alcohol consumption. Medical history including pre-pregnancy height and weight, parity, history of infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of DM, and reasons behind potential PA restriction during early pregnancy will also be collected.</li> <li><i>Fitbit activity tracker and mobile application</i></li> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	33	250	Magrogomia (DW > 4.5kg)
<ul> <li>Neonatal hypoglycemia (glucose &lt;2.5 mmol/L)</li> <li>253 Pre-eclampsia</li> <li>254 APGAR scores</li> <li>255</li> <li>255</li> <li>257 Research participant characteristics form</li> <li>258 Sociodemographic data to be assessed include marital status, educational level, household income, type of housing, working status during pregnancy, smoking status, and alcohol</li> <li>259 income, type of housing, working status during pregnancy height and weight, parity, history of</li> <li>261 infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of</li> <li>262 DM, and reasons behind potential PA restriction during early pregnancy will also be</li> <li>263 collected.</li> <li>264</li> <li>265 Fitbit activity tracker and mobile application</li> <li>266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>267 connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>268 on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	34	251	Nacrosoffia ( $D \le 4.3 \text{Kg}$ )
<ul> <li>253 · Pre-eclampsia</li> <li>254 · APGAR scores</li> <li>255</li> <li>256 Data collection</li> <li>257 Research participant characteristics form</li> <li>258 Sociodemographic data to be assessed include marital status, educational level, household</li> <li>259 income, type of housing, working status during pregnancy, smoking status, and alcohol</li> <li>260 consumption. Medical history including pre-pregnancy height and weight, parity, history of</li> <li>261 infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of</li> <li>262 DM, and reasons behind potential PA restriction during early pregnancy will also be</li> <li>263 collected.</li> <li>264</li> <li>265</li> <li>264</li> <li>266</li> <li>266</li> <li>267 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>267 connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>268 on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	35	252	Neonatai nypogiyeemia (giucose <2.5 mmol/L)
<ul> <li>254 APGAR scores</li> <li>255</li> <li>256 Data collection</li> <li>257 Research participant characteristics form</li> <li>258 Sociodemographic data to be assessed include marital status, educational level, household</li> <li>259 income, type of housing, working status during pregnancy, smoking status, and alcohol</li> <li>260 consumption. Medical history including pre-pregnancy height and weight, parity, history of</li> <li>261 infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of</li> <li>262 DM, and reasons behind potential PA restriction during early pregnancy will also be</li> <li>263 collected.</li> <li>264</li> <li>265 Fitbit activity tracker and mobile application</li> <li>266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>267 connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>268 on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	36	253	· Pre-eclampsia
<ul> <li>255</li> <li>256 Data collection</li> <li>257 Research participant characteristics form</li> <li>258 Sociodemographic data to be assessed include marital status, educational level, household</li> <li>259 income, type of housing, working status during pregnancy, smoking status, and alcohol</li> <li>260 consumption. Medical history including pre-pregnancy height and weight, parity, history of</li> <li>261 infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of</li> <li>262 DM, and reasons behind potential PA restriction during early pregnancy will also be</li> <li>263 collected.</li> <li>264</li> <li>265 Fitbit activity tracker and mobile application</li> <li>266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>267 connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>268 on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	37 38	254	· APGAR scores
<ul> <li>256 Data collection</li> <li>257 Research participant characteristics form</li> <li>258 Sociodemographic data to be assessed include marital status, educational level, household</li> <li>259 income, type of housing, working status during pregnancy, smoking status, and alcohol</li> <li>260 consumption. Medical history including pre-pregnancy height and weight, parity, history of</li> <li>261 infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of</li> <li>262 DM, and reasons behind potential PA restriction during early pregnancy will also be</li> <li>263 collected.</li> <li>264</li> <li>265 Fitbit activity tracker and mobile application</li> <li>266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>267 connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>268 on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	39 40	255	
<ul> <li>257 <i>Research participant characteristics form</i></li> <li>258 Sociodemographic data to be assessed include marital status, educational level, household</li> <li>259 income, type of housing, working status during pregnancy, smoking status, and alcohol</li> <li>260 consumption. Medical history including pre-pregnancy height and weight, parity, history of</li> <li>261 infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of</li> <li>262 DM, and reasons behind potential PA restriction during early pregnancy will also be</li> <li>263 collected.</li> <li>264</li> <li>265 <i>Fitbit activity tracker and mobile application</i></li> <li>266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>267 connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>268 on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	40	256	Data collection
<ul> <li>Kesearch participant characteristics form</li> <li>Sociodemographic data to be assessed include marital status, educational level, household</li> <li>income, type of housing, working status during pregnancy, smoking status, and alcohol</li> <li>consumption. Medical history including pre-pregnancy height and weight, parity, history of</li> <li>infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of</li> <li>DM, and reasons behind potential PA restriction during early pregnancy will also be</li> <li>collected.</li> <li><i>Fitbit activity tracker and mobile application</i></li> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	42	257	Description and the superstantistics form
<ul> <li>Sociodemographic data to be assessed include marital status, educational level, household</li> <li>income, type of housing, working status during pregnancy, smoking status, and alcohol</li> <li>consumption. Medical history including pre-pregnancy height and weight, parity, history of</li> <li>infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of</li> <li>DM, and reasons behind potential PA restriction during early pregnancy will also be</li> <li>collected.</li> <li><i>Fitbit activity tracker and mobile application</i></li> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	43	257	Keseurch participant characteristics form
<ul> <li>income, type of housing, working status during pregnancy, smoking status, and alcohol</li> <li>consumption. Medical history including pre-pregnancy height and weight, parity, history of</li> <li>infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of</li> <li>DM, and reasons behind potential PA restriction during early pregnancy will also be</li> <li>collected.</li> <li><i>Fitbit activity tracker and mobile application</i></li> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	44 45	258	Sociodemographic data to be assessed include marital status, educational level, household
<ul> <li><sup>47</sup> 260 consumption. Medical history including pre-pregnancy height and weight, parity, history of infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of DM, and reasons behind potential PA restriction during early pregnancy will also be collected.</li> <li><sup>52</sup> 263 collected.</li> <li><sup>54</sup> 265 <i>Fitbit activity tracker and mobile application</i></li> <li><sup>56</sup> 266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	46	259	income, type of housing, working status during pregnancy, smoking status, and alcohol
<ul> <li><sup>48</sup> 261 infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of DM, and reasons behind potential PA restriction during early pregnancy will also be collected.</li> <li><sup>52</sup> 264</li> <li><sup>54</sup> 265 <i>Fitbit activity tracker and mobile application</i></li> <li><sup>56</sup> 266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	47	260	consumption Medical history including pre-pregnancy height and weight parity history of
<ul> <li><sup>49</sup> 261 Informity detailed, existing enformentiesses, instory of GDW and/of GW, family instory of DW, and reasons behind potential PA restriction during early pregnancy will also be</li> <li><sup>51</sup> 263 collected.</li> <li><sup>52</sup> 264</li> <li><sup>54</sup> 265 <i>Fitbit activity tracker and mobile application</i></li> <li><sup>56</sup> 266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li><sup>58</sup> 267 connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li><sup>59</sup> 268 on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	48	261	infertility treatment existing chronic illnesses history of GDM and/or GH family history of
<ul> <li>262 Divi, and reasons bennu potential PA restriction during early pregnancy will also be</li> <li>263 collected.</li> <li>264</li> <li>265 <i>Fitbit activity tracker and mobile application</i></li> <li>266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>267 connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>268 on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	49	201	DM and rangenes behind notantial DA restriction during early programmy will also be
<ul> <li><sup>51</sup> 263 confected.</li> <li><sup>52</sup></li> <li><sup>53</sup> 264</li> <li><sup>54</sup></li> <li><sup>55</sup> 265 <i>Fitbit activity tracker and mobile application</i></li> <li><sup>56</sup></li> <li><sup>56</sup> 266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li><sup>58</sup> 267 connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li><sup>59</sup> 268 on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	50	202	and reasons bening potential I A restriction during early pregnancy will also be
<ul> <li>264</li> <li>265 <i>Fitbit activity tracker and mobile application</i></li> <li>266 At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>267 connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>268 on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	51	263	conected.
<ul> <li>Fitbit activity tracker and mobile application</li> <li>Fitbit activity tracker and mobile application</li> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	52 53	264	
<ul> <li>Fitbit activity tracker and mobile application</li> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	54		
<ul> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	55	265	Fitbit activity tracker and mobile application
<ul> <li>At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be</li> <li>connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	56	200	At mean its and posticing at is simple a similar density of the (P'd') dia 111
<ul> <li>connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education</li> <li>on device and application will be carried out. The tracker is worn daily from recruitment to</li> </ul>	57	266	At recruitment, each participant is given a wristband activity tracker (Fitbit) that will be
<sup>59</sup> 268 on device and application will be carried out. The tracker is worn daily from recruitment to	58	267	connected via Bluetooth to a Fitbit application downloaded onto her smartphone. Education
	59 60	268	on device and application will be carried out. The tracker is worn daily from recruitment to

2		
3	269	end of 20 weeks gestation inclusive except during bathing or water activities Participants are
4	200	advised to synchronize the tracker data at least once a week. For data to be valid wear time
5	270	advised to synchronize the tracker data at reast once a week. For data to be valid, wear-time
6	271	must be at least 4 days per week (including one weekend day) and at least 10 hours per day.
7	272	Steps per day will be recorded by the tracker. Data will be reported as continuous and
8	272	steps per day will be recorded by the tracker. Data will be reported as continuous and
9	273	categorical variables. Continuous variables include mean weekday and weekend steps per day
10	274	and mean steps per day in first and second trimesters. Categorical variables include
17	275	classification into a CDC recommendation-based steps per day physical inactivity/activity
12	276	continuum defined as follows: (1) <5000 (sedentary); (2) 5000-7499 (low active); 3) 7500-
14	277	9999 (somewhat active): 4) 10,000-12,499 (active): and 5) >12,500 (highly active) <sup>35</sup> .
15		(content and a content o); (f) = content o); (a content o); (a content o) = content o(content o); (content
16	278	
17		
18	279	International Physical Activity Questionnaire (IPAQ)
19	200	The IDAO lang version will be self a dministered during the first visit at lass than 12 weeks
20	280	The IPAQ long version will be self-administered during the first visit at less than 12 weeks
21	281	gestation in the first trimester and again between 20-24 weeks gestation in the second
22	282	trimester. It is a set of 4 questionnaires assessing 5 activity domains (occupation,
23	283	transportation, household, leisure, and sedentary) independently in the past 7 days, and may
24	284	be administered via self or telephone <sup>42</sup> . Well-established and validated in adults aged 15-69
25 26	285	years it is available in both English and Chinese <sup>43,44</sup> . It has been used in studies involving
20	205	pregnant woman <sup>29,45</sup>
27	280	pregnant women-3,°.
29	287	Data will be reported as continuous and categorical variables. Continuous variables include
30	288	median MET-minutes per week (MET-min/wk) and interquartile ranges computed for each
31	200	denotion and denotion (availation and denote interview DA) and anterquartice ranges computed for each
32	289	domain, subdomain (waiking, moderate-intensity PA and vigorous-intensity PA) and overall
33	290	total PA. MET or metabolic equivalent is a unit that measures energy expenditure in
34	291	multiples of the resting metabolic rate <sup>46</sup> . Categorical variables include classification into low,
35	292	moderate, high levels of PA according to the IPAQ scoring protocol.
36		
3/	293	
38 20	204	Madiaal nacoud data
39 40	294	
41	295	Additional data to be collected include ethnicity, weight changes during pregnancy, weight at
42	296	6 weeks post-delivery obstetric outcomes of GDM GH preeclampsia and IUGR and
43	207	nonotal outcomes comprising APCAP scores protorm birth macrosomia and nonotal
44	297	
45	298	nypogiycemia.
46	299	
47	233	
48	300	Participant feedback form
49 50		
50	301	After the end of 20 weeks gestation, experience with the activity tracker and mobile
52	302	application in terms of usability and troubleshooting will be evaluated. Compliance level will
53	303	be quantified by number of days per week.
54		
55	304	
56	205	Statistics
57	202	Stausuus
58	306	Descriptive statistics of PA levels in the 1st and early 2nd trimester will be presented
59 60	307	Categorical variables will be presented as n (%) while continuous variables will be presented
00		
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		o   P a g e

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2	200	(CD) an analian (CD). Maan atom and have a line MET minutes are used
4	308	as mean (SD) of median (SD). Mean steps per day and median ME1-minutes per week
5	309	test respectively. MeNemer's test will be used to compare adoptery behavior between
6 7	211	semesters. Similar tests will be employed to assess for a difference in DA levels between
8	311 21 <b>2</b>	wookdows and wookends
9	312	weekdays and weekends.
10	313	Binary logistic regression will be used to evaluate the association of early pregnancy PA with
11 12	314	GDM and/or GH. Crude (unadjusted) and adjusted regression models will be included.
13	315	Potential confounders will be identified a priori based on literature review and controlled for
14	316	in the regression analyses. Potential interactions between covariates and early pregnancy PA
15	317	will be tested using cross-product terms. Secondary analyses on the bio-socio-demographic
16 17	318	factors associated with sedentary behavior, as well as the association between early
18	319	pregnancy PA level and maternal weight at 6 weeks post-delivery, will follow the methods of
19	320	the primary analyses, but are exploratory having not been powered to formally test the
20	321	hypotheses. All regression analyses will be presented as odds ratios (ORs) with 95%
21	322	confidence intervals (CIs).
22	272	Statistical analyses will be performed using IBM SPSS Statistics version 23.0 (IBM Corp.
24	323	Armonk NY USA) $P$ values of <0.05 will be considered statistically significant
25	524	Armonk, IV. I., OSAY). I values of 0.05 will be considered statistically significant.
26 27	325	
28	326	Safety parameters
29	520	
30 31	327	Adverse effects and device monitoring will be carried out at the subsequent 4-weekly routine
32	328	prenatal visits. Any adverse skin reaction to the wristband will be recorded. Participation will
33	329	be stopped at any time the Principal Investigator decides that continuing on could be harmful
34	330	to the participant.
35 36	331	
37		4
38	332	Data management
39 40	333	All data will be coded for confidentiality. Hardcopy data will be stored at the research site
41	334	under lock and key. Electronic data can only be accessed and retrieved from the secured
42	335	website by the participant and research team. Electronic data will be exported on a fortnightly
43	336	basis. All data obtained will be entered into and stored on the institution Research Electronic
44 45	337	Data Capture (REDCap) system, a centralised secured data management server with
46	338	password access. Data integrity monitoring will be carried out monthly by the principal
47	339	investigator and co-investigators if deemed necessary.
48	240	
49 50	340	
51	341	Patient and Public Involvement
52	242	Detionts and the multic many net investigation the devial annual of the response question and
53	342	Patients and the public were not involved in the development of the research question and
54 55	343	outcome measures.
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3	347	Ethics and dissemination
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Ethical approval was obtained from the Centralised Institutional Review Board of SingHealth (reference 2017/2836). Informed written consent will be sought from all participants. 

Results from this study will be submitted to the funding organization and peer-reviewed 

journals for consideration of publication both online and in print. Results will also be 

- under the state of the sta presented at relevant meetings, conferences and medical forums in either oral or poster
- formats.

1		
2 3	379	Conclusion
4 5	575	
6	380	Ine I-AC1 study aims to be the first comprehensive study objectively evaluating the PA levels and patterns in early pregnancy, and their association with GDM and/or GH in the
7 8	382	multi-ethnic population of Singapore. In addition to addressing these important scientific
9	383	knowledge gaps, from a clinical perspective, the study itself may increase awareness of PA
10 11	384	during early pregnancy while demonstrating the potential of wearable activity trackers as an
12	385	objective measure of PA in health research. More importantly, we hope the results of the study facilitate the identification of high risk mothers to be for targeted intervention, and
13 14	387	help formulate strategies for interventional efforts.
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1 2		
3 4	412	Acknowledgements
5 6 7	413 414	The authors would like to thank Professor Satvinder Singh Dhaliwal for providing statistical advice during the conception of this study.
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_ 3 ⊿	590	Author statement
5	591	MC was involved in all aspects of the study from conception, design, recruitment and
6 7	592	manuscript writing. KHT and SBA provided critical review of the design and writing. As
7 8	593	Principle Investigator, SBA takes overall responsibility for the work. All authors agree to be
9	594	accountable for their work.
10	FOF	
11 12	595	
13	596	Funding statement
14	507	This work is supported by the AM-ETHOS Duke-NUS Medical Student Fellowship (AM-
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18	600	(IPRAMHO).
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22	602	Conflict of interests
23	602	The authors dealers no notantial conflicts of interest with respect to the authorship and/or
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## I-ACT: Integrated study on effect of Activity on ComplicaTions in pregnancy – study protocol of a multiethnic prospective cohort study

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19	7	Meijin Cai BSc Hons <sup>1,a</sup> . Kok Hian Tan MBBS <sup>2,b</sup> and Seng Bin Ang
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21	8	MBBS <sup>1,3,4,3,6</sup> .
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#### Abstract

Introduction: Physical activity (PA) during first 20 weeks of pregnancy may lower risks of gestational diabetes mellitus (GDM) and gestational hypertension (GH), though evidence of association remains inconclusive. Current studies rely heavily on subjective assessment of PA levels. Wearable activity trackers provide a convenient and objective surrogate index for PA validated by evidence-based steps/day categorization along a physical inactivity/activity continuum. I-ACT primarily aims to examine objectively measured PA levels and patterns in first and second trimesters of pregnancy and the association with GDM and/or GH in Singapore, a multi-ethnic Asian population. Secondary aims include investigating the bio-socio-demographic factors associated with sedentary behavior, and association of early pregnancy PA level with maternal weight at 6 weeks post-delivery. Results may facilitate identification of high-risk mothers-to-be and formulation of interventional strategies. Methods and analysis: Prospective cohort study that will recruit 408 women at first antenatal visit at <12 weeks gestation. Baseline bio-socio-demographic factors and PA levels assessed by participant characteristics form and the International Physical Activity Questionnaire (IPAQ) respectively. An activity tracker (Fitbit) will be provided to be worn daily from date of recruitment to end of 20 weeks gestation. Tracker-recorded data will be synchronized with an application on participant's smartphone. Compliance will be reinforced with fortnightly reminders. After 20 weeks, a second IPAQ and a feedback form will be administered. GDM screened at 24-28 weeks gestation. GH diagnosed after 20 weeks gestation. Maternal weight assessed at 6 weeks post-delivery. Appropriate statistical tests will be used to compare continuous and categorical PA measurements between first and second trimesters. Logistic regression will be used to analyse associations. Ethics and dissemination: Ethical approval obtained from the Centralised Institutional Review Board of SingHealth (reference 2017/2836). Dissemination of results will be via peer-reviewed research publications both online and in print, conference presentations, posters, and medical forums. (299 words) Keywords: Physical activity, gestational diabetes mellitus, pregnancy-induced hypertension, pregnancy 

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9	82	• Objective measurement of PA levels and patterns in early pregnancy
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11	84	<ul> <li>Participant non-compliance despite reinforcement measures</li> </ul>
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#### Introduction

Physical activity (PA) is defined as any bodily movement produced by skeletal muscles that 

- results in energy expenditure<sup>1</sup>. Current recommendations encourage women with
- uncomplicated pregnancies to continue or initiate safe physical activities in pregnancy<sup>2</sup>. More
- specifically, the CDC recommends 30 min/day for five days each week of moderate-intensity
- aerobic activity, which can be met by walking<sup>3</sup>. Concerns about safety have been refuted by
- literature demonstrating that moderate exercise in low-risk pregnancy improves maternal
- well-being without associated risks of birth weight reduction or preterm birth<sup>4</sup>.
- Physical inactivity or sedentary behavior in early pregnancy (<20 weeks gestation) is a
- potential modifiable risk factor for two common obstetric complications, gestational diabetes
- mellitus (GDM) and gestational hypertension (GH). GDM is defined as carbohydrate
- intolerance that develops during pregnancy<sup>5</sup>. It complicates 1.8-25.1% of pregnancies worldwide depending on country and definition, with South-East Asia having the second
- highest prevalence at 8.1-18.3<sup>6</sup>. Approximately 8-20% of pregnancies are affected in
- Singapore<sup>7</sup>. Overall prevalence of GH, otherwise known as pregnancy-induced hypertension,
- is estimated at 10-12%<sup>8,9</sup>, though the local incidence has not been established. Perinatal
- sequelae of GDM and GH include macrosomia, neonatal hypoglycemia, preterm birth,
- intrauterine growth restriction (IUGR), and low APGAR scores. Both metabolic disorders are
- also proven risk factors of future type 2 diabetes<sup>10</sup>.
- Current literature investigating the association between PA in early pregnancy and the development of GDM has shown a significant risk reduction of up to 24%<sup>11-14</sup>, though a few other studies have found a null association or insufficient evidence<sup>15-17</sup>. The association with GH is even less clear from the limited literature available<sup>18-21</sup>. All these studies utilised questionnaires as a measurement of PA. Studies that incorporate an objective means of measurement have been scarce<sup>22,23</sup>, which may partially explain the inconclusive evidence of association thus far. A Norway-based study investigating objectively recorded PA in early pregnancy and GDM reported that the adjusted odds ratio for GDM decreased 19% with every 3159 step-increase per day<sup>22</sup>. Based on these existing studies, physical inactivity in early pregnancy is a modifiable risk factor worth targeting
- This is especially so in the Asian population. PA during first half of pregnancy has been shown to be low in an Asian urban setting<sup>24</sup>, and similarly lower when compared to non-Asian counterparts<sup>23,25</sup>. In Singapore, no published study on objectively measured PA levels in pregnancy could be found, and studies on association of subjectively-measured early pregnancy PA levels with both obstetric complications are rare. Padmapriva et al. investigated the change in PA levels from a pre-pregnancy to pregnancy state using a structured self-constructed questionnaire administered at 26-28 weeks gestation scored based on the International Physical Activity Questionnaire (IPAQ) short form<sup>26</sup>. The same study group further reported that a higher PA during the first 6 months of pregnancy was associated with lower prevalence of GDM, especially among overweight/obese women<sup>27</sup>. However, the utilisation of a questionnaire at 26-28 weeks gestation that relied on recall of PA levels during first 6 months of pregnancy and the year before subjected the results to a high level of recall bias. Therefore, the paucity of local research on objectively-measured PA levels in early pregnancy and association with obstetric metabolic outcomes warrants additional prospective studies.

## BMJ Open

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155	As evident from existing studies, current assessment of pregnancy PA levels relies heavily on
156	subjective, self-reporting questionnaires deemed to be the most feasible method with the
157	absence of a gold standard and clear guidelines <sup>28</sup> . The inclusion of more objective
158	measurements is being advocated <sup>29</sup> . Consumer wearable activity trackers operate through a 3-
159	axis accelerometer, providing an alternative convenient and objective means of assessing PA
160	levels during pregnancy. The accuracy, reliability and efficacy of wearable activity trackers
161	in various health programs have been validated <sup>30-33</sup> , although a systematic review has found
162	the research-grade accelerometer or pedometer to be superior in terms of accuracy <sup>34</sup> . Steps
163	per day categorization along a physical inactivity/activity continuum based on CDC
164	recommendation has also been elucidated, with 5000 (sedentary) and 10,000 (active) being
165	the primary anchor points <sup>35</sup> . The correlation between steps per day and activity counts per
166	day, from which activity intensity and duration were derived, was proven to be positive and
167	strong, thus validating its use as an index for PA <sup>36</sup> . Step count estimated by Fitbit activity
168	trackers among healthy adults has also been validated in a separate study <sup>37</sup> . Furthermore,
169	various measured parameters such as step count and moderate-to-vigorous PA (MVPA) of
170	different Fitbit activity trackers models have also been validated in the particular population
171	of pregnant women in free living conditions <sup>38</sup> .
177	Through the use of both Fithit activity trackers and the $IPAO$ , this prospective multi-ethnic
173	cohort study primarily aims to investigate the PA levels and patterns in early pregnancy (1st
174	trimester and 2nd trimester up to 20 weeks gestation) as well as the effect of PA in early
175	pregnancy on development of GDM and/or GH. Secondary aims include assessing the bio-
176	socio-demographic factors associated with sedentary behavior, and examining the association
177	between early pregnancy PA level and maternal weight at 6 weeks post-delivery.
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#### Methods and analysis

#### **Study design**

In this prospective cohort study, pregnant women will be recruited at outpatient clinics in KK Women's and Children's Hospital, a major public hospital in Singapore that sees a high volume of obstetrics & gynaecology consultations. Recruitment started in June 2018 and is expected to end in 2019. This study will follow the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline for cohort studies. 

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#### **Recruitment and eligibility criteria**

All obstetricians running outpatient general obstetrics & gynaecology clinics will refer suitable candidates for recruitment. All recruitment will be done via face-to-face contact by the research team. 

Inclusion criteria are singleton pregnancy, first antenatal visit less than 12 weeks gestation, and ages between 21 and 50 years old inclusive. Exclusion criteria are severe medical and/or psychological co-morbidity (including New York Heart Association (NYHA) class IV heart failure, end-stage renal disease, assistive device-dependent for mobility, cognitive 

impairment, and loss of rational thinking), and skin conditions (including contact dermatitis, pemphigus vulgaris and bullous pemphigoid) precluding the wearing of activity trackers. 

#### **Power analysis**

Given that prevalence of GH has not been investigated in Singapore, GDM prevalence is used instead. Assuming that GDM proportion is 17.6%<sup>39</sup> and that PA can reduce risk of GDM by 30%, a sample of 367 mothers will be required at 80% power and 5% level of significance. Assuming a dropout rate of 10%, a sample of 408 mothers will be recruited into the study. 

#### **Participant timeline**

Recruitment is at first antenatal visit less than 12 weeks gestation, during which Fitbit education, International Physical Activity Questionnaire (IPAQ) and participant characteristics form are done (Fig. 1). PA level monitoring occurs henceforth until end of 20 weeks gestation inclusive. The standard 4-weekly antenatal visits will continue during this period. After 20 weeks gestation, a second IPAQ and a feedback form are administered either at regular antenatal visits before 24 weeks gestation, or over the phone/email. Routine GDM screening takes place between 24 and 28 weeks gestation. The final follow-up occurs at the 6th week after delivery to obtain participants' weight. 

#### **Ensuring compliance**

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3	220	Annroaches to enhance compliance include rainferring the importance of commitment to
4	230	Approaches to eminance compliance menude remoting the importance of communent to
5	231	wearing the activity trackers daily at the time of recruitment, and making fortingity follow-
6	232	up calls up until 20 weeks gestation. Compliance will also be recorded as part of Fitbit use
/ 8	233	assessment in the participant feedback form at the end of 20 weeks gestation.
9 10	234	
11	235	Outcome measures
12 13	236	Primary outcomes include the following:
14	237	GDM – diagnosed if the following threshold value at any time point is exceeded after
16	238	a 75 g oral glucose tolerance test (OGTT) between 24 and 28 weeks gestation based
17	239	on the International Association of Diabetes and Pregnancy Study Groups (IADPSG)
18	240	criteria: fasting venous plasma glucose of $>5.1$ mmol/L. 1-hour venous plasma
19 20	241	glucose of $\geq 10.0$ mmol/L, and 2-hour venous plasma glucose $\geq 8.5$ mmol/L <sup>40</sup> .
20 21	242	GH = diagnosed as new onset hypertension (systelic blood pressure >140 mmHg
21	242	and/or diastolic blood pressure >00 mmHg) measured on two occasions at least four
23	243	hours apart after 20 weeks sostation in the absence of proteinurie or new signs of and
24	244	nouis apart arter 20 weeks gestation in the absence of proteinuna of new signs of end-
25	245	organ dystunction <sup>41</sup> .
26 27	246	Secondary outcomes include the following:
28	247	• Weight at 6 weeks post-delivery
29 30	248	· Weight gain in pregnancy
31	249	· Intrauterine growth restriction (IUGR)
32	250	· Preterm birth (GA $\leq 37$ weeks)
33	251	· Macrosomia (BW >90th percentile or >4.0 kg)
34	251	Nacrosofina (BW > your percentile of > 1.0 kg)
35	252	Dra calampsia
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37 38	254	· APGAR scores
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41	256	Data collection
42 43	257	Research participant characteristics form
44	250	Sociodemographic data to be assessed include marital status, advicational loval, household
45 46	250	income type of housing, working status during programmery smoking status, and alcohol
40 47	239	aconsumption Modical history including are programey height and weight parity history of
48	260	consumption. Medical instory including pre-pregnancy neight and weight, parity, instory of
49	261	infertility treatment, existing chronic illnesses, history of GDM and/or GH, family history of
50	262	DM, and reasons behind potential PA restriction during early pregnancy will also be
51	263	collected.
52 53	264	
54 55	265	Fitbit activity tracker and mobile application
56	266	At recruitment each participant is given a wristhand activity tracker (Fithit) that will be
5/ 50	267	connected via Bluetooth to a Fithit annlication downloaded onto her smartnhone. Education
50 59	207	on daviag and application will be carried out. The treaker is were doily from recentity art to
60	208	on device and application will be carried out. The tracket is worn daily from recruitment to

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3	269	end of 20 weeks gestation inclusive except during bathing or water activities Participants are
4	200	advised to synchronize the tracker data at least once a week. For data to be valid wear time
5	270	advised to synchronize the tracker data at reast once a week. For data to be valid, wear-time
6	271	must be at least 4 days per week (including one weekend day) and at least 10 hours per day.
7	272	Steps per day will be recorded by the tracker. Data will be reported as continuous and
8	272	steps per day will be recorded by the tracker. Data will be reported as continuous and
9	273	categorical variables. Continuous variables include mean weekday and weekend steps per day
10	274	and mean steps per day in first and second trimesters. Categorical variables include
17	275	classification into a CDC recommendation-based steps per day physical inactivity/activity
12	276	continuum defined as follows: (1) <5000 (sedentary); (2) 5000-7499 (low active); 3) 7500-
14	277	9999 (somewhat active): 4) 10,000-12,499 (active): and 5) >12,500 (highly active) <sup>35</sup> .
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16	278	
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18	279	International Physical Activity Questionnaire (IPAQ)
19	200	The IDAO lang version will be self a dministered during the first visit at lass than 12 weeks
20	280	The IPAQ long version will be self-administered during the first visit at less than 12 weeks
21	281	gestation in the first trimester and again between 20-24 weeks gestation in the second
22	282	trimester. It is a set of 4 questionnaires assessing 5 activity domains (occupation,
23	283	transportation, household, leisure, and sedentary) independently in the past 7 days, and may
24	284	be administered via self or telephone <sup>42</sup> . Well-established and validated in adults aged 15-69
25 26	285	years it is available in both English and Chinese <sup>43,44</sup> . It has been used in studies involving
20	205	pregnant woman <sup>29,45</sup>
27	280	pregnant women-3,°.
29	287	Data will be reported as continuous and categorical variables. Continuous variables include
30	288	median MET-minutes per week (MET-min/wk) and interquartile ranges computed for each
31	200	denotion and denotion (availation and denote interview DA) and anterquartice ranges computed for each
32	289	domain, subdomain (waiking, moderate-intensity PA and vigorous-intensity PA) and overall
33	290	total PA. MET or metabolic equivalent is a unit that measures energy expenditure in
34	291	multiples of the resting metabolic rate <sup>46</sup> . Categorical variables include classification into low,
35	292	moderate, high levels of PA according to the IPAQ scoring protocol.
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38 20	204	Madiaal nacoud data
39 40	294	
41	295	Additional data to be collected include ethnicity, weight changes during pregnancy, weight at
42	296	6 weeks post-delivery obstetric outcomes of GDM GH preeclampsia and IUGR and
43	207	nonotal outcomes comprising APCAP scores protorm birth macrosomia and nonotal
44	297	
45	298	nypogiycemia.
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48	300	Participant feedback form
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50	301	After the end of 20 weeks gestation, experience with the activity tracker and mobile
52	302	application in terms of usability and troubleshooting will be evaluated. Compliance level will
53	303	be quantified by number of days per week.
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56	205	Statistics
57	202	Stausuus
58	306	Descriptive statistics of PA levels in the 1st and early 2nd trimester will be presented
59 60	307	Categorical variables will be presented as n (%) while continuous variables will be presented
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3 4	308	as mean (SD) or median (IQR). Mean steps per day and median MET-minutes per week
5	309	test respectively. McNemar's test will be used to compare sedentary behavior between
7	311	semesters. Similar tests will be employed to assess for a difference in PA levels between
8 9	312	weekdays and weekends.
10	313	Binary logistic regression will be used to evaluate the association of early pregnancy PA with
11 12	314	GDM and/or GH. Crude (unadjusted) and adjusted regression models will be included.
13	315	Potential confounders will be identified a priori based on literature review and controlled for
14	316	in the regression analyses. Potential interactions between covariates and early pregnancy PA
15 16	317	will be tested using cross-product terms. Secondary analyses on the bio-socio-demographic
17	318	factors associated with sedentary behavior, as well as the association between early
18 10	319	the primary analyses but are exploratory having not been powered to formally test the
20	320	hypotheses All regression analyses will be presented as odds ratios (ORs) with 95%
21 22	322	confidence intervals (CIs).
22	323	Statistical analyses will be performed using IBM SPSS Statistics version 23.0 (IBM Corp.,
24 25	324	Armonk, N.Y., USA). <i>P</i> values of <0.05 will be considered statistically significant.
26 27	325	
28	326	Safety parameters
29 30	327	Adverse effects and device monitoring will be carried out at the subsequent 4-weekly routine
31 32	328	prenatal visits. Any adverse skin reaction to the wristband will be recorded. Participation will
33	329	be stopped at any time the Principal Investigator decides that continuing on could be harmful
34	330	to the participant.
35 36	331	
37 38	332	Data management
39 40	333	All data will be coded for confidentiality. Hardcopy data will be stored at the research site
41	334	under lock and key. Electronic data can only be accessed and retrieved from the secured
42 43	335	website by the participant and research team. Electronic data will be exported on a fortnightly
43 44	336	basis. All data obtained will be entered into and stored on the institution Research Electronic
45	337	Data Capture (REDCap) system, a centralised secured data management server with
46 47	338	investigator and as investigators if deemed necessary
48	222	investigator and co-investigators if deemed necessary.
49 50	340	
51 52	341	Patient and Public Involvement
53	342	Patients and the public were not involved in the development of the research question and
54 55	343	outcome measures.
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3	347	Ethics and dissemination
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Ethical approval was obtained from the Centralised Institutional Review Board of SingHealth (reference 2017/2836). Informed written consent will be sought from all participants. 

Results from this study will be submitted to the funding organization and peer-reviewed 

journals for consideration of publication both online and in print. Results will also be 

- under the state of the sta presented at relevant meetings, conferences and medical forums in either oral or poster
- formats.

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2 3	379	Conclusion
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6	380	Ine I-AC1 study aims to be the first comprehensive study objectively evaluating the PA levels and patterns in early pregnancy, and their association with GDM and/or GH in the
7 8	382	multi-ethnic population of Singapore. In addition to addressing these important scientific
9	383	knowledge gaps, from a clinical perspective, the study itself may increase awareness of PA
10 11	384	during early pregnancy while demonstrating the potential of wearable activity trackers as an
12	385	objective measure of PA in health research. More importantly, we hope the results of the study facilitate the identification of high risk mothers to be for targeted intervention, and
13 14	387	help formulate strategies for interventional efforts.
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1 2		
3 4	412	Acknowledgements
5 6 7	413 414	The authors would like to thank Professor Satvinder Singh Dhaliwal for providing statistical advice during the conception of this study.
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3 4	590	Author statement
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32	608	Figure Legend
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35	609	Figure 1. Timeline of the I-ACT prospective cohort study.
36	610	*Participants will continue to attend routine antenatal visits throughout the study period
37	611	during which blood pressure monitoring will be done.
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